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Microstructural Study and Antibacterial Response of an AlCoCrCuFeMoNi High-Entropy Alloy

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Biomedical alloys present a unique combination of physical and biological properties such as high biocompatibility and corrosion resistance. Titanium and its alloys are the most widely used materials for dental implants. Unfortunately, metal implants have a great difference in stiffness compared with human bones, which causes an undesirable heterogeneous (uneven) distribution of stresses. Porous implants have the important advantage of a lower stiffness. Through powder metallurgy technique, some Ti-based materials have been processed in order to obtain porous prototypes for biomedical application. However, the level of mechanical failures is still high. As example, one direct consequence of the constant use of dental implants during food chewing is mechanical wear, which generates distortion of the original shape of implant and accumulation of wear particles. In addition, to released particles, certain biological processes take place between the implant and bone inducing bacterial colonies formation which affect the physical integrity of implant and patient health. Hence, there is a growing interest of the biomedical industry for the development of new alloys with better mechanical properties.

In addition to titanium, other elements have proven to be biocompatible: Fe, Mo, Ni, Co and Cr (316 LQ stainless steel, Ti6AlV4, CoCrMo). Through the concept of high-entropy alloys (HEAs), novel materials with superior properties have been developed. Some HEAs with Mo have demonstrated a noticeable enhanced of corrosion resistance under different environments, but most of these alloys exhibit hardness and elastic modulus that exceeds the corresponding to human bones [1]. However, experimental results gave evidence about Cu addition improves the ductility of HEAs. Because Cu has shown bactericidal properties, it is expected that addition of this element (to reduce Mo-HEAs hardness), may provide antimicrobial properties [2]. Hence, the aim of this investigation is the synthesis of an AlCoCrCuFeMoNi HEA alloy through mechanical alloying and sintering, to evaluate its microstructure, hardness and antibacterial activity.

The conditions for the alloy preparation are the same as those described in our previous work [3]. The microstructure of prepared samples was characterized using a SEM JEOL JSM-7401F microscope and hardness was evaluated through a LECO LM-300AT Vickers tester using 15 s as dwell time and 200 g of load. The alloy bactericidal capacity was evaluated by an antimicrobial activity assay. A Gram positive (Staphylococcus aureus) and a Gram negative (Escherichia coli) bacteria were used. The cultures were incubated for 24 h in presence of the alloy and compared with a blank. Then, some agar plates were inoculated with 50 µL of the culture media and incubated at 37°C for 24 h.

The mechanical results give evidence about Cu addition reduces the hardness of the AlCoCrFeMoNi alloy, from 980 to 340 HV. The biointegration refers to the chemical bond that occurs between the maxillary bone and the ceramic part of the implant. Due to the embrittlement of ceramic materials, dental implants limit their use as coatings on metal parts. The hydroxyapatite is widely used in dental implants because it is the mineral phase of bone. In addition to hydroxyapatite, other ceramic materials such as aluminum oxide are frequently used for the biointegration process. In our case, the microstructure of AlCoCrCuFeMoNi alloy is composed by alumina, which could benefit the biointegration. Collected data from the antimicrobial assay showed a decrease of bacteria proliferation in colony forming-units (UFC/mL) in S. aureus (Fig. 2), suggesting an antimicrobial activity of alloy. On the other hand, for E. coli a significant antimicrobial effect was not observed. The above suggest that the alloy could have a specific antimicrobial effect being a possible candidate for biomedical applications.

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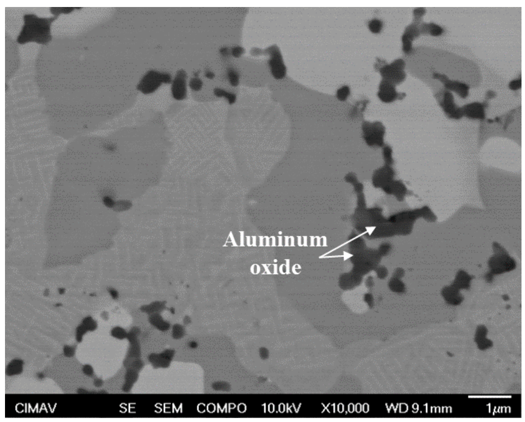

Figure 1. FE-SEM micrograph showing the microstructure of the AlCoCrCuFeMoNi alloy and Al_2O_3 generation.

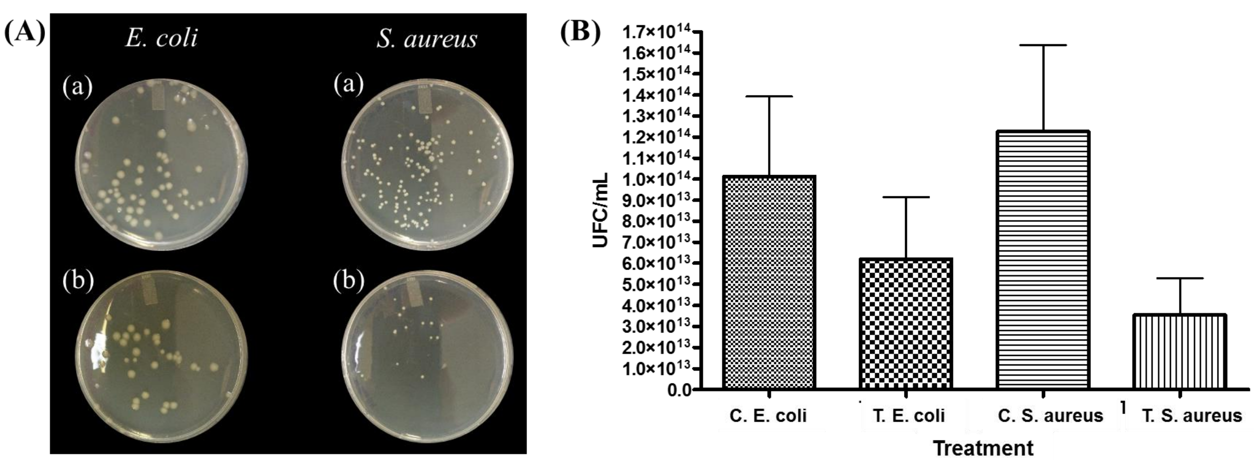

Figure 2. (A) Images of S. aureus and E. coli after 24 h of incubation: (a) control and (b) AlCoCrCuFeMoNi and (B) comparative plot of bacterial colonies density.

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